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EXPERIMENTAL INVESTIGATION OF DIRECT EVAPORATIVE COOLER WITH HEMP AND ABACA COOLING PAD MATERIAL

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ABSTRACT

Evaporative cooling is environment friendly and more efficient air cooling method. The efficiency of evaporative cooling systems increases with an increase in temperature and decrease in humidity. Therefore in hot and dry climates, evaporative cooling can save a large amount of energy used for conventional air conditioning systems. Direct evaporative cooler (DEC) uses a wetted pad with large air water contact surface area through which air is passed at uniform rate to make it saturated. However this process is accompanied by an increase in humidity which is sometimes not desirable.

Thus, it is seen that variety of materials that can be used as cooling media in direct evaporative cooler is very large. Hence there is need to analyze the performance of alternative materials in terms of saturation efficiency and cooling capacity. Further, the performance of a cooler using Hemp and Abaca as cooling media has not been analyzed. Hence the attempt is made to fabricate and analyze the performance of such cooler in the present work.

The efficiency of evaporative cooling systems increases with an increase in temperature and decrease in humidity. In the developed direct evaporative cooler 15-20% effectiveness is more in case of Hemp as cooling pad material as compared to the Abaca cooling pad material. Enhancement in effectiveness is 10-15% more in case water flow rate at 220 LPH in all cooling pad material as compared to 180LPH and 200 LPH. Average outlet dry bulb temperature was varying between 240 C and 280 C. cooling capacity can be

improved by increasing the water flow rate through the cooling pad and the dry bulb temperature of incoming air can be reduced below its wet bulb temperature.

Keywords: Abaca cooling pad, cooling capacity, cooling efficiency, Effectiveness, Hemp cooling pad.

I. INTRODUCTION

Nowadays, great attention is paid to the environment, energy saving and energy efficiency. Energy production often adversely affects the environment and increases greenhouse gas emissions. Despite this, the global energy consumption grows from year to year. That is why the question of the development of new, cleaner and more efficient technologies has been raised acutely in recent years. A large part of the world's energy is consumed by ventilation and air-conditioning. Practically in each modern building ventilation and air-conditioning systems are installed. Even many of the old buildings where possible, are equipped with modern ventilation systems. Many of building facilities, such as hospitals and industrial buildings, have specific requirements for ventilation and air conditioning systems.

One of the most energy-intensive processes in the ventilation and air-conditioning is the process of cooling. Traditional systems based on the compressor cycle consume a lot of energy. Refrigerants contained in compressor circuits are often very harmful to the environment. These factors led to the active development of evaporative coolers. Conventional direct evaporative coolers consist of a large water reservoir, a pump that draws water from the reservoir and discharges it through spray nozzles directly into air stream or through cooling pads. The direct evaporative cooler cools the air when the air comes in contact with water in the wetted media (cooling pads).During evaporation of water in air stream, the required heat is taken from air itself.

To counter periods of extreme temperature that affect in-house environments and therefore production, Cool air Evaporative Cooling Pad Systems are used with outstanding success. When large quantities of air are pulled through Evaporative Cooling Pads that are saturated with water, a substantial cooling effect is realized due to the evaporation of that water. Used in conjunction with Cool air fans, a temperature reduction of 10-25 degrees is commonplace. Suited for virtually all Geographic locations, the Cool air Evaporative Cooling System delivers the greatest economic benefits to areas where higher temperatures during longer periods of time are normal. Evaporative Cooling Pads (Evap. Pads) are a product developed for horticultural and agricultural cooling applications. Evap. Pads are made of a specially formulated cellulose paper, impregnated with insoluble anti-rot salts, stiffening saturates and wetting agents. Evap. Pads have a cross fluted configuration that provides maximum cooling when warm air passes through the wet Evap. Pad material.

Researchers performed a theoretical study of performance of evaporative cooler with different cooling pad shapes and materials are made [4]. Rectangular, cylindrical and hexagonal shaped pads of rigid cellulose, corrugated paper, high density polythene packing and aspen fiber material are considered [2]. Geometrical parameters of pad shape like area, volume are calculated for air velocities between 0.75 to 2.25 m/s. Based on weather data of Bhopal, India, inlet condition of 39.9 0C dry bulb temperature and relative humidity of 32.8 % is selected for the analysis. Saturation efficiency, dry bulb temperature of outlet air and cooling capacity are estimated. Saturation efficiency decreases with increase in mass flow rate of air having highest value of 91 % for hexagonal shaped pad with aspen material. It is followed by cylindrical (90%) and rectangular (89 %) pads. The cooling capacity increases with air mass flow rate having minimum value of 35826 kJ/h for rectangular pad with cellulose material for air mass flow rate of 0.3 kg/s.[5] They made theoretical performance analysis of direct evaporative cooling. Different materials were considered in the analysis; rigid cellulose, high density polythene, aspen fiber and corrugated paper material. The results of the analysis showed that the aspen fiber material had the highest efficiency of 87.5%, while the rigid cellulose material had the lowest efficiency at 77.5%.The outlet temperature and cooling capacity varied between28.8°C and 26.5°C and 13408 KJ/h and 56686 KJ/h for the two materials, respectively [1].

In this paper, the performances of cooling pad types namely Hemp and Abaca are evaluated experimentally and effect of Air velocity, mass flow rate on the cooling efficiency and cooling capacity are investigated.

II. DESIGN AND DEVELOPMENT OF EVAPORATIVE COOLER:

The experimental set up consists of major components such as cooling pad material, inlet/outlet duct, water tanks, fan with motor, pump and required instrumentation. The actual experimental set up is fabricated in local workshop having all manufacturing facilities. Figure 3 shows the schematic of the experimental set up while Fig. 4 show the actual experimental set up.

The developed evaporated cooler is shown in Fig 1; it consists of the different components like cooling pad materials, inlet/outlet duct, water tanks, and fan with motor, pump, vane anemometer, and hygrometer. On the basis of the criteria mentioned the design of the individual component was prepared and corresponding parameter (i.e. relative dimensions and material for all components) were calculated. The procedure of design and calculations for each component is mentioned below.

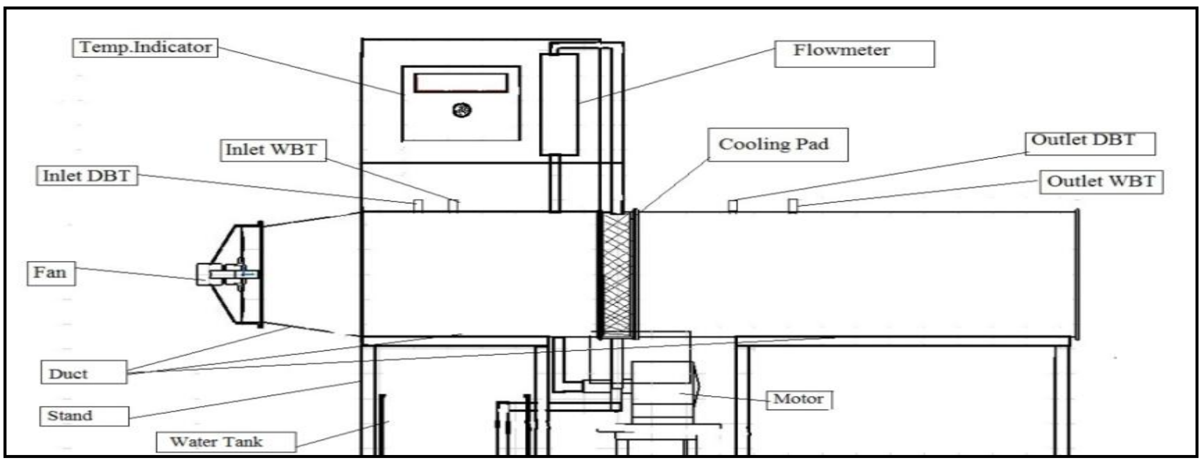

Fig1.Schematic view of experimental set up

2.1 Materials and methods:

Hemp is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. Advantages of hemp are high moisture retention capacity and ease of manufacture with no skin irritations. Hence hemp fiber is chosen as media for evaporative cooler also we Abaca was tested under the same condition. Hemp fibers cannot be used in their normal shape because it is difficult to retain the shape after wetting. According to theory of cooling pad material either compact or widely spaced bank can be used for the purpose. But due to fabrication limitations of the fixing plate for pad, widely spaced bank is chosen for the experimental set up. Surface area of pad forms the wetted surface for evaporation of water. Water pump used to circulate water over the cooling pads. A fan draws hot and dry air over the ropes and water gets evaporated on the surface of cooling pad. Heat required for evaporation is taken from air as well as water. Hence air gets cooled and its moisture content gets increased. Make up water is added in the tank if required after running the unit for long time. The necessary instrumentation is done for measurement of different parameters.

In order to study the direct evaporative cooling, experimental setup will be fabricated with facility for cooling efficiency measurement. In this work to compare the performance of DEC system different pad materials like Hemp and Abaca are selected. The proposed pad materials are arranged in setup to evaluate the performance of pad materials.

The purpose of the present study is to experimentally investigate the performance of direct evaporative cooling with hemp, abaca as cooling pads materials. The block diagram of experimental setup to be developed is as given in Fig 3.1 The set up includes a tunnel, a blower, rigid pad media, a recirculating pump, nozzles and a water collecting tank. A connecting piece of rectangular cross section connects the test section to the blower whereas other end of the test section connects the diffuser. Ambient air can be forced to circulate through the tunnel by fan. Cooling water can be sprayed from above the test section by nozzles onto the top surface of cooling pad. The falling water can be collected in the water collecting tank and can be re-circulated through the pump. A provision can be made for easy changing of cooling pad of different materials and thicknesses. A number of calibrated thermocouples are fitted to measure dry bulb and wet bulb temperatures at the inlet and outlet of the test section. The thermocouples are connected to data logger for recording various temperatures. Hot wire anemometer was used for measuring air flow rate. In order to carry out the experimentation, the setup is validated with the help of cooling pads materials.

Fig2. Photographic view of actual setup

Fig3. Cooling pad

By using the fabricated experimental setup and hemp, abaca evaporative cooling pad materials the experimentation was conducted under various mass flow rates.

2.2 Experimental Set Up Details

Duct selection consists of finding out two parameters:

1. To decide dimensions of duct
2. To find out cross section area of duct

Duct height and width are considered 500mm and 500mm respectively.

Duct Specifications given as follows

Table.1 Duct Specifications

Material	Dimensions (mm)		Gauge	Hydrodynamic Length
	Height	Width		(m)
GI Sheet	500	500	22	2

1. To find out cross section area of duct:

   Cross sectional Area of Duct (A) = Height (H) X Width (W) A= 0.5×0.5 m² = 0.25m²

   To find out Perimeter of duct: 2×[(Height)+(Width)] =2× [(0.5) + (0.5)] =2m

2.3 DESIGN CRITERIA

a) The main parameter considered when evaluating the performance of direct evaporative coolers is the Saturation Effectiveness (ε), which can be defined as [5],

$$\varepsilon = \frac{(DBT_1 - DBT_2)}{(DBT_1 - WBT_2)} * 100 \text{ ………… (1)}$$

Where DBT1 and DBT_2 denote the inlet and outlet dry bulb temperatures of the air at the test section respectively and WBT2 is the wet bulb temperature.

The value of the Saturation Effectiveness depends on the following factors:

b) Cooling capacity which is given by ,

$$Q = m_a * C_p * (DBT_1 - DBT_2) * 3600 \text{ ………… (2)}$$

Where Q is the sensible heat (W) and m_a is Mass Flow rate of air (Kg/s)

c) Relation water/air (Mw/Ma): This is the relation between the mass flow of atomized water and air flow. A high value shows a higher contact area between air and water and thus higher η.

III. PERFORMANCE OF DEVELOPED EVAPORATOR COOLER:

This gives the test methodology adopted for evaluating the performance of developed evaporator cooler and corresponding observations recorded during the experimentation. It also describes the measuring instruments used during testing with specifications for different purposes.

The experiment was performed on the developed Evaporative cooler using different testing methodologies.

3.1 Testing methodologies:

The experiment was conducted in month of April with maximum air flow rate. Two different materials namely Hemp and Abaca were tested one by one. Initially set up was run for about 20 min to ensure steady state condition. Then dry and wet bulb temperature of air at inlet and outlet were measured using thermocouple and recorded. The saturation effectiveness of cooling pads was calculated using the relation as mentioned in data reduction.

Mass flow rate of air was changed from 1.1 m/s to 2.5 m/s .In case of whole day testing average mass flow rate of air 1.8 m/s is kept constant. All the readings of different pad material at different water flow rate were taken respectively. Mass flow rate of water is varied in a range of 180 LPH to 220 LPH by using Rota meter.

Dry bulb temperature and wet bulb temperature of inlet air are slightly changed for every flow rate of water. Three sets of reading are recorded for each pad at different water flow rates i.e. for 180,200 and 220.

3.2 Experimental procedure:

Effects of air velocity and mass flow rate of water on cooling efficiency and water consumption in a period of 20 min were studied. Eight levels of air velocity (1.1, 1.3, 1.5, 1.7, 1.9, 2.1, 2.3, 2.5 ms^{-1})

VI. FIGURES AND TABLES:

1.1 GRAPHS

a)

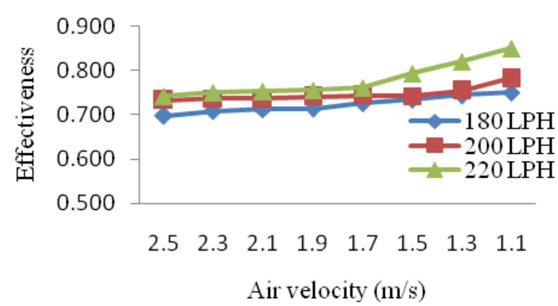

Fig4.Variation of effectiveness for different water mass flow rate and air velocity for Hemp

b)

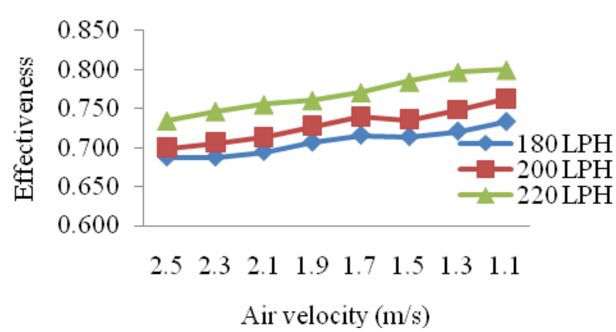

Fig5.Variation of effectiveness for different water mass flow rate and air velocity for Abaca

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c)

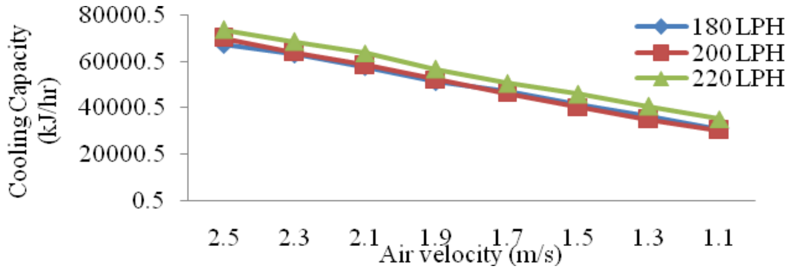

Fig6. Variation of cooling capacity at different water flow rate for Hemp

d)

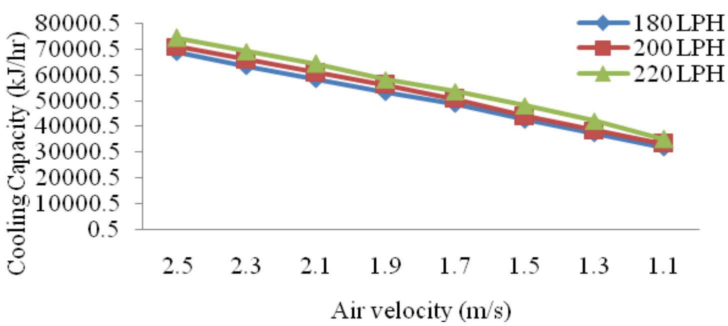

Fig7. Variation of cooling capacity at different water flow rate for Abaca

4.2 **Tables: Variation In The Effectiveness With Different Air Velocity For Different Water Flow Rate**:

Table 2

For 180 LPH

Air Velocity	**Effectiveness**	
m/s	**Hemp**	**Abaca**
2.5	0.699	0.688
2.3	0.708	0.688
2.1	0.713	0.695
1.9	0.714	0.707
1.7	0.726	0.716
1.5	0.735	0.714
1.3	0.744	0.721
1.1	0.750	0.734

Table 3

for 200 LPH

Air Velocity	**Effectiveness**	
m/s	**Hemp**	**Abaca**
2.5	0.733	0.699
2.3	0.737	0.706
2.1	0.737	0.713
1.9	0.740	0.727
1.7	0.744	0.739
1.5	0.742	0.736
1.3	0.754	0.748
1.1	0.782	0.763

Table 4

for 220 LPH

Air Velocity	**Effectiveness**	
m/s	**Hemp**	**Abaca**
2.5	0.743	0.734
2.3	0.750	0.746
2.1	0.754	0.755
1.9	0.755	0.761
1.7	0.761	0.771
1.5	0.794	0.785
1.3	0.821	0.797
1.1	0.850	0.800

4.3 **Tables: Variation In The Cooling Capacity With Different Air Velocity For Different Water Flow Rate**:

Table 5

For 180 LPH

Air Velocity	**Cooling capacity(kJ/hr)**	
m/s	**Hemp**	**Abaca**
2.5	67453.0875	68873.15
2.3	63363.3003	63363.30
2.1	57853.4481	58449.87
1.9	51264.3465	53422.84
1.7	47316.5658	48765.03
1.5	41323.8915	42601.95
1.3	36552.4731	37290.90
1.1	30929.0157	31866.25

Table 6

for 200 LPH

Air Velocity	**Cooling capacity(kJ/hr)**	
m/s	**Hemp**	**Abaca**
2.5	70293.21	71003.2
2.3	64016.53	65976.2
2.1	58449.87	60835.5
1.9	52343.59	56120.9
1.7	46350.92	50696.3
1.5	40471.85	43880.0
1.3	35075.60	38398.5
1.1	30304.18	33115.9

Table7

for 220 LPH

Air Velocity	**Cooling capacity(kJ/hr)**	
m/s	**Hemp**	**Abaca**
2.5	73843.38	74553.4125
2.3	68589.13	69242.3694
2.1	63817.72	64414.1484
1.9	56660.59	58279.4676
1.7	50696.32	53593.2531
1.5	46010.10	48140.2035
1.3	40613.85	42090.7266
1.1	35302.81	34990.4016

V. RESULTS AND DISCUSSIONS :

1.2 THE EFFECT OF AIR VELOCITY ON COOLING EFFECTIVENESS :

The experiments were conducted for two different cooling pad materials, so in accordance to study of effectiveness on air velocity is evaluated, the above 2 graphs a), b) and tables2,3,4 shows the variation of effectiveness when the experiment was conducted using different air velocity from 1.1 m/s to 2.5 m/s. From the above graphs it is clear that the effectiveness for any cooling pad material is more in case of water flow rate is 220 LPH. Especially when we are considering cooling pad materials then we got the effectiveness is more in case of Hemp material as compared to Abaca material.

1.3 THE EFFECT OF AIR VELOCITY ON COOLING CAPACITY:

The experiments were conducted for different cooling pad materials, so in accordance to study of cooling capacity on air velocity is evaluated, the above 2 graphs c),d) and tables 5,6,7 shows the variation of cooling capacity when the experiment was conducted using different air velocity from 1.1 m/s to 2.5 m/s. From the above graphs it is clear that the cooling capacity for any cooling pad material is going to increase while increasing the air velocity for all water flow rate ranging from 180 LPH to 220 LPH.

VI. CONCLUSIONS

1.4 In this work direct evaporative cooler has been developed and tested experimentally. The effect of air velocity, water flow rate, different cooling pad material, on cooling capacity and effectiveness has been evaluated different period of time.

The following conclusions have been arrived at, from the experimental investigation carried out in the present work on direct evaporative cooler. In the developed direct evaporative cooler 15-20% effectiveness is more in case of hemp as cooling pad material as compared to the Abaca cooling pad material. Enhancement in effectiveness is 10-15% more in case water flow rate at 220 LPH in all cooling pad material as compared to 180LPH and 200 LPH Average outlet dry bulb temperature was varying between 24^0 C and 28^0 C. Cooling capacity can be improved by increasing the water flow rate through the cooling pad and the dry bulb temperature of incoming air can be reduced below its wet bulb temperature .Water consumption of the cooler varies between 180 LPH and 220 LPH depending on the mode of operation and the material used.

6.2. Developed evaporator cooler have been successfully tested and results are quite promising, still there are some areas on which the same work can be further extended so that effectiveness and cooling capacity can be improved successfully. The details of which are follows,

Efforts can be with modification in cooling pad system so that its use can be extended for longer period in cooling process Controlled cooling environment can be maintained in the cabinet and its effect can be analyzed to improve the effectiveness. Evaporative cooling is environment friendly and more efficient air cooling method. The efficiency of evaporative cooling systems increases with an increase in temperature and decrease in humidity. Therefore in hot and dry climates, evaporative cooling can save a large amount of energy used for conventional air conditioning systems. Direct evaporative cooler (DEC) uses a wetted pad with large air water contact surface area through which air is passed at uniform rate to make it saturated. However this process is accompanied by an increase in humidity which is sometimes not desirable. Thus, it is seen that variety of materials that can be used as cooling media in direct evaporative cooler is very large. Hence there is need to analyze the performance of alternative materials in terms of saturation efficiency and cooling capacity. Further, the performance of a cooler using hemp and abaca as cooling media has not been analyzed. Hence the attempt is made to fabricate and analyze the performance of such cooler in the present work.

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